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Soldier Performance in a Moving Command Vehicle Under Manned, Teleoperated, and Teleoperated Cruise Control Modes Under Day and Night Conditions

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14. ABSTRACT

Soldiers will be required to perform missions using remote technology with increasing frequency as the U.S. Army transforms. Teleoperation requires that Soldiers perform missions that will require them to be at greater standoff distances at the cost of degraded sensory information and resulting limited system performance. Historically, teleoperated systems have had capabilities that are twice the error rate and time required to perform a mission. This is due to the limited field of view, depth perception, vestibular cues, and other immersion reducing characteristics of remote operation. The need to provide operational improvements to the historically degraded teleoperation mode is being recognized by the U.S. Army in many areas, including route clearing and mine detection systems. The Rabbit 2.0 system allows several modes of operation that are purported to reduce Soldier workload. These modes include manned operation, teleoperation, and teleoperation with cruise control. The study was designed to examine these modes of operation, comparing the subjective workload, stress, and motion sickness as well as course completion time, average speed, and driving error in terms of lateral drift. Soldiers operated the Rabbit 2.0 system over a secondary course while maintaining proper speed and road edge following in all three modes under both day and night conditions. Data for vehicle position and speed were collected at a rate of 5 Hz while subjective ratings of workload, stress, and motion sickness were collected at the end-points of the course runs. Participants were four U.S. Army Soldiers recruited from the 10th Mountain Division. Separate ANOVA analyses were used for day and night conditions. ANOVAs revealed significant differences for the effects of control mode on workload for both day and night conditions as well as for the effect of speed on lateral drift distances. Subjective ratings of accelerator quality were affected by mode for both day and night conditions. Video display and speedometer quality ratings were noted as poorer under night conditions for both teleoperated modes.

15. SUBJECT TERMS

teleoperation, robotics, Soldier performance, workload, motion sickness

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1. Introduction

Teleoperated systems development has been increasing for U.S. Army applications and the Army is continually attempting to field systems that further remove Soldiers from harm on the battlefield (Trouvain, 2006). For the job of mine detection and route clearing, many remote systems have been designed and used, but not many have overcome the hurdle of increased Soldier workload through technology. Chen et al. (2007) describe the various factors that limit the perceptual and situational awareness of the operator such as limited field of view, limited depth perception, uncoupled orientation and motion, control and sensor information lags, and others. Muth et al. (2006) further describe the performance effects of uncoupled motion for both command and control vehicles and teleoperated systems.

Teleoperated land systems for route clearing, mine clearing, and convoy operations have had significant increases in attention by the U.S. Army. Teleoperation is the remote control of a system, usually via radio link, that includes visual and or other feedback to "immerse" the operator into the remote environment. The task of driving can induce high workload in military systems (Wojciechowski, 2004). Teleoperated systems, on the other hand, are known to have significantly increased workload as compared to on-board or manned driving (Dixon et al., 2003; Schipani, 2003; Scribner and Dahn, 2008). Solutions to this workload problem have been sought in both (1) the improvement of control and display qualities in the operator station, and (2) through the reduction of operator tasks through automation. However, the primary issue is that of loss of sensory information via remote visual, auditory and even tactile displays that represent a fraction of the information an operator receives within the true environment. This information-limited constraint is viewed as the primary source of reduced performance and increased workload in teleoperated systems. This information-limited environment is highly analogous to an imposed "cognitive tunneling" effect described by Hancock and Warm (1989) and imposed by remote sensors, displays, and controls.

This study was designed in order to assess the Soldier performance and interface quality characteristics of a teleoperated route reconnaissance vehicle system with two teleoperated modes with respect to on-board driving as a baseline. Previous research has shown that teleoperation modes dramatically increase Soldier workload and operational errors over on-board driving, and a data-driven tradeoff of removing Soldiers from potentially harmful or lethal environments is a strong consideration in the development of these systems, which may have a high performance cost.

1.1 Teleoperated Control Modes

The U.S. Army Research Laboratory (ARL) has continually attempted to find ways to improve the Soldier's performance and survivability by leveraging technology.

The ability to control teleoperated systems will depend mainly upon human factors engineering (HFE) interface design characteristics, and without suitably designed controls and displays, there will be an additional workload cost in such systems.

Anecdotal data from a mine clearing system using cruise control suggests that high workload was attributed to the use of cruise control in that system (Haas et al., 1997). Participants used a joystick controller that may have confused the operators. Haas also noted that HFE concerns for this type of slow-moving, sensor-driven system would rely on operator vigilance to counteract the high potential for tedium in such a task.

1.2 Teleoperated Systems Performance Literature

Performance of teleoperated systems is generally degraded as compared to similar manned systems and sometimes half that of on-board driving (Scribner and Gombash, 1998). Specifically, performance time to complete a test course for teleoperated driving is about twice that of on-board driving. The number of errors (obstacles hit) has been shown to be about double that of on-board or manned driving (Scribner and Gombash, 1998). Since then, Scribner and Dahn (2008) found that teleoperator performance and workload ratings were improved with cruise control, to eliminate the task of continuous speed control, than without it. These measures of lateral drift, or variance in vehicle position from the lane center, may not have been practically significant and were on the order of a few centimeters in difference, albeit for very low speeds only (Scribner and Dahn, 2008).

The issue of the source of high workload under teleoperated conditions is likely due to a limited sensory information condition. This limited sensory information condition has been studied in the past by Scribner and Gombash (1998) and will be discussed further in this report.

1.2.1 Motion Effects and Motion Sickness in Telerobotic Systems

Motion sickness (MS) is defined as the physiological response of the body when the visually perceived movement and vestibular system sense of movement receive disparate cues of motion. MS is often the term used for various types of illness and has been attributed to the body's innate response to neurotoxin poisoning (Triesman, 1977). When the vestibular and visual systems do not have similar input, the postrema area of the brain is triggered to begin a vomiting response. This mismatch theory of system cues put forth by Reason and Brand (1975) can cause simulator sickness, created by visual movement cues with a lack of movement cues, motion, or seasickness, caused by the perceived vestibular motion without visual input (Muth et al., 2006; Wertheim et al., 1995; Wertheim, 1998). MS in teleoperated systems has long been a problem due to both the lack of visual fidelity that is associated with the visual systems and the disparate motion cues from either a stationary or moving command platform.

Tasks on moving platforms are difficult, and focused concentration on tasks within such systems can elicit motion sickness effects (Cowings, et al., 1999; Hill and Tauson 2005). The Future Combat System Lead System Integrator performed a demonstration in which the operator teleoperated robotic vehicles from a moving command vehicle (Kamsickas, 2003). The results showed that motion made all tasks more difficult, compared to an exercise in a simulated environment, and some tasks (e.g., editing plans and maps, and target acquisition) became almost impossible to perform due to the difficulty experienced by the operators in attempting to stabilize their hand movements. Operators also tended to over-steer their robotic vehicles when their own vehicle was turning in disparate directions from the teleoperated vehicle being controlled.

According to Schipani (2003), motion also makes cognitive tasks more challenging. Schipani evaluated Soldiers' cognitive performance while in a moving vehicle, and found significant accuracy and speed decrements in performance. Degradations were found in areas such as time-sharing, selective attention, inductive reasoning, memorization, and spatial orientation.

The measurement of motion sickness and simulator sickness can be accomplished with one set of measures, as the physiological outcome is the same but can vary widely among individuals. Several measures have been used in recent literature concerning motion sickness, but one in particular has been useful in recent efforts. For this study, the MS inventory by Gianaros (2001) was selected for use because of its ability to classify MS further into specific areas of effect: gastrointestinal, central nervous system, peripheral nervous system, and sophite-related.

1.2.2 Workload in Telerobotic Systems

Performance and workload have been assessed for many different types of systems. It has been proposed that semi-autonomous modes of teleoperated control will yield the least amount of operator workload. It has also been proposed that using cruise control will lower operator workload as well. These are all logical assumptions that remain to be tested.

Schipani et al. (1998) found that workload increased as mission distance increased, from 500, 1000, and 2000 m. He also found that workload increased as a function of required operator intervention in a semi-autonomous system. The converse of this, of course, is that workload would be lower for higher levels of autonomy.

Glumm et al. (1996) found that when using a computer-aided teleoperation (CAT) method for extending a teleoperated vehicle's path, cognitive workload was increased in comparison to direct teleoperation. This may have been due to the distance between waypoints, which was set at 1 m. This rate of waypoints for the speed of teleoperation may have been considered high workload. Speed averages were 7.6 and 4.7 km/h for normal and CAT modes, respectively.

Scribner and Dahn (2008) found that workload ratings for manned driving, teleoperation, and teleoperation with cruise control were all significantly stratified with teleoperation exhibiting the highest perceived workload, ~1.7 times higher than manned driving, and teleoperation with cruise control the next ranking, ~1.6 times higher than manned driving workload. This finding is highly consistent with past research with teleoperated ground systems.

1.2.3 Teleoperation Performance Reduction

No specific theory regarding the increased workload of teleoperation is available; however, there are some explanatory concepts that have been pursued by some researchers. In many teleoperated systems, information and control systems are degraded relative to the operator insofar as cameras and video links are provided for visual and occasionally for auditory information. Control-display links for physical operation of teleoperated systems often have an associated delay in system response to control actions. The first explanation of reduced sensory information comes from older research performed by Scribner and Gombash (1998), who found that teleoperation driving accuracy tasks were improved when a stereovision system was compared to a monoscopic viewing system. The three-dimensional (3-D) effect of the stereovision system was suitable to significantly reduce road edge obstacle contact rates by up to 33%. A wide field of view condition, using a three-camera array, was also attributed to lower workload scores as measured by the NASA Task Load Index. This evidence indicates that sensory information degradation in teleoperation is responsible for creating higher task workload and stress conditions for comparable manual on-board driving tasks. This is analogous to driving in the rain at night when visibility is reduced and attentional demand is noticeably increased thus increasing task demand stress and workload.

Some control lag was evident in this study but was not controlled for in the experiment. This data was collected from a stationary teleoperation platform. It is posited that a combinatorial effect of sensory degradation, control lag, and uncoupled motion effects are the primary contributors to increased task demand stress, increased task times, and higher error rates in teleoperation environments. The typical reduction in performance and increase in workload for teleoperated systems as compared to on-board or manual driving has been known to be approximately half the performance (Scribner and Gombash, 1998) and nearly double the cognitive workload (Scribner and Dahn, 2008) of on-board manned operation, respectively. In general, until systems are created that can provide natural, high-definition full field of view, immersive 3-D audio, near-zero control delay, and counteract the effects of uncoupled motion, teleoperated systems will suffer performance below that of on-board driving in conventionally operated driving systems.

2. Hypotheses

We expected that manned driving, teleoperation, and teleoperation with cruise control would yield statistically significant performance differences. Specifically, we expected that performance would be significantly improved for manned operation mode compared to the two teleoperated remote modes. We further expected that among teleoperated modes, cruise control would yield performance differences that were significantly superior to teleoperation mode alone. These three modes are operationally defined in section 3.3.

We expected that subjective workload ratings would be substantially higher for both teleoperated modes as compared to manned driving mode. We also expected that workload ratings for the teleoperation-only mode would be significantly higher as compared to teleoperation with cruise control mode.

We expected that subjective motion sickness ratings would be substantially higher for all remote modes as compared to manned driving mode. We also expected that motion sickness ratings for teleoperation-only mode would be significantly higher as compared to teleoperation with cruise control mode. We also expected that motion sickness ratings would be significantly apparent for the higher speed condition.

3. Methods

The primary operational task in this study was to maintain center of lane position while operating a teleoperated system at maintained speeds of 8 and 15 mph. Participants were instructed to operate a HMMWV in manned or either of two teleoperated modes (operation modes = 3). These conditions were duplicated and identical under both day and night driving conditions with the exception of different visual sensors that were required for each application and associated level of ambient illumination.

3.1 Participants

Participants were four U.S. Army Infantry Soldiers recruited from the 10th Mountain Division, Ft. Drum, NY. All participants met requirements for 20/30 visual acuity. Ranks ranged from E-3 to E-6 (Mode = E-4). Age ranged from 22 to 34 years (M = 26, SD = 5.48). Time in service ranged from 1.2 to 16.6 years (M = 7.1, SD = 6.86). Three of the participants reported that they were low in susceptibility to motion sickness while one reported moderate susceptibility.

3.2 Apparatus

3.2.1 Volunteer Agreement Affidavit

A Volunteer Agreement Affidavit (VAA) (appendix A) was given to each test participant to review prior to participating in the study. This form was used as the single VAA for several studies performed simultaneously that were all aligned under one research protocol number ARL-20098-09008, entitled “A Comparison of Soldier Performance in a Moving Command Vehicle Under Manned, Teleoperated and Semi-Autonomous Robotic Mine Detector System Control Modes.” The VAA used describes this study and others. Upon reading the document, test participants were able to ask all questions concerning their participation in the study. Once they agreed to participate, they signed the document.

3.2.2 Demographic Questionnaire

A demographic questionnaire (appendix B) was administered to collect age, gender, Military occupational specialty (MOS), years in that MOS, and other background information.

3.2.3 TITMUS II Vision Testing Device

Participants were screened for 20/30 both-eye visual acuity, far distance using a Titmus II visual-testing device.

3.2.4 ARL Robotics Outdoor Test Facility

The test course is a 960-m-long course that is similar in nature to a secondary road. This is located at the ARL Outdoor Robotics Test Facility at Aberdeen Proving Ground (APG), MD. This area has been used in previous tests of teleoperated and autonomous vehicles and operator performance. Vehicle measurement plates were aligned and placed on the center of the road for data collection purposes at 30-m intervals. These plates also served as visual identifiers of the road center for vehicle alignment. This track was driven equally in left-handed laps for a total of four laps (3840 m) or 2.4 mi.

3.2.5 HMMWV Teleoperated Vehicle

An armored HMMWV was equipped to be driven in manned on-board mode in normal driver's seat with standard driving controls. This same HMMWV was operated remotely from the rear right passenger seat of a MRAP vehicle under two different teleoperated modes. The teleoperation operator position, controls, and displays within the MRAP vehicle are shown in figure 1. The HMMWV to be controlled was outfitted with visual camera sensors for use while in teleoperation mode. The sensors used were varied for both day and night conditions. The day conditions used normal color day CCD cameras with a 55° field of view. The night cameras were low-light monochrome CCD cameras with a 55° field of view. These were switched as needed for day and night operation.

Figure 1. Soldier teleoperating HMMWV from MRAP vehicle.

3.2.6 Teleoperated Control Station

The Rabbit Control Station was placed in the rear of an MRAP vehicle for operations on the move. The video set-up for this study was to use high center camera view as the analog display (left) and a driver-referenced center camera as the redundant digital display (right). The right-side display included vehicle status information such as speed and drive gear currently engaged. In all experimental trials except for manned driving, the HMMWV was followed by the MRAP Command Vehicle. The control station had two LCDs for visual displays (figure 1).

The vehicle controls consisted of a steering wheel with dead-man switches on the back side of the wheel in case steering control was lost. Throttle and brake hand-levers were mounted on the right and left upper sides of the steering control, respectively.

3.2.7 Workload Rating Scale

The NASA-TLX has been validated with mathematical processing tasks of various levels for workload assessment. A modified version of the NASA TLX (appendix C) (Hart and Staveland, 1988) was used to quantify participant workload ratings under various conditions. The three subscales for physical demand, mental demand, and temporal demand were used. A pair-wise comparison was used to develop individual weightings for each workload aspect.

3.2.8 Motion Sickness Assessment Questionnaire.

The Motion Sickness Assessment Questionnaire (MSAQ) (appendix D) (Gianaros et al., 2001) was used to quantify participant motion sickness ratings under the various conditions.

3.2.9 Control and Display Ratings Questionnaires.

A Modified Cooper-Harper for assessing Unmanned Vehicle Displays (MCH-UVD) assessment scale (Cummings et al., 2006) was used to assess the quality of controls (appendix E) and displays (appendix F) for each condition.

3.3 Teleoperated System Control Modes

The Rabbit 2.0B System employed a remotely controlled HMMWV commanded from an RG-31 command vehicle using an operator control unit mounted in the right rear of the MRAP. The Rabbit 2.0B system had various camera configurations available including a center-of-vehicle mounted analog camera (on top of the cab), forward-looking windshield-referenced digital camera, and a rear-facing camera for reverse gear. The system was capable of being operated in one of three modes: manned, teleoperated, and teleoperated with cruise control. These modes are described as follows:

- Manned Driving – consisted of driving the HMMWV control station vehicle around the course in the same manner as the remote modes.
- Teleoperation – the remote operation of a vehicle using a video camera and primary video display in conjunction with a steering wheel and hand controls for acceleration and braking. There is currently no audio feedback system.
- Teleoperation with cruise control – the previously described mode with the addition of continuous speed control via cruise control, essentially locking the desired speed and easily disengaged with a cancellation of the cruise or with a brake input.

3.4 Teleoperated Vehicle Operation Scenario

The participants reported to APG and were provided an overview of the study, at which time initial questions could be asked about the purpose of the study and what was expected. Participants were asked to read and sign the informed consent form if they agreed to participate.

The demographics questionnaire and eye exam were then administered. Participants were then familiarized with the purpose and method of response for the workload, motion sickness, and control/display rating questionnaires. Prior to any training, participants received a safety briefing on the operation of teleoperated vehicles and ranges. Participants were informed that they could withdraw from the study at any time for any reason, especially if they felt that they had become motion sick.

Following this training, all four experimental conditions were presented to the participants. There was an optional rest period between trials, yet none of the participants chose to rest in between trials. Workload, motion sickness, and control/display questionnaires were all administered after each four-lap experimental trial.

3.5 Design and Analysis

The design of this experiment was a 3 × 2 repeated measures design. Separate 3 × 2 factorial repeated measures ANOVAs were used for both day and night conditions data. The treatment variables had three levels of control mode and two levels of speed. Tukey least significant difference (LSD) was used for pair-wise post-hoc comparisons.

3.5.1 Independent Variables

The first variable manipulated in this study was the control mode of vehicle operation for the Rabbit 2.0B system, which at the time of test included a HMMWV as the teleoperated vehicle. Levels of control mode were manned driving (for baseline comparison), basic teleoperation, and teleoperation with cruise control. The second variable manipulated in this study was speed of the vehicle, which was either 8 or 15 mph. The time of day was also manipulated and was either mid-day from 11 a.m. to 3 p.m. or night from 9:30 p.m. to 1 a.m.; however, this last variable was considered to be separate due to confounding visual sensors and ambient illumination, and two separate analyses were performed based upon the differences in visual sensors employed for teleoperated viewing.

3.5.2 Dependent Variables

Dependent variables included vehicle performance data (lane-center deviation and road-edge crossings), workload, motion sickness, and control-display ratings. Lane-center deviation, or lateral drift, was measured on a scale of inches, and the numbers of lane edge misses were counted for totals. Lateral drift is a measure of deviation from the center of the lane as determined by the position of the vehicle passing over lane center ground marking plates, which were read by laser sensors as they passed over each plate. Lateral drift was collected at each ground marker plate every 30 m and was recorded for future analysis. Road edge crossing errors were recorded when the vehicle did not register a ground marker sensor plate pass, indicating that the vehicle would have traversed to the road edges or further to either the left or right side.

Subjective ratings of workload and motion sickness were also assessed using the NASA-TLX and Motion Sickness Assessment Questionnaire, respectively. Additionally, all primary controls (throttle, brake, steering control) and displays (primary visual display and speedometer) were assessed with a MCH-UVD rating scale inventory to present means and standard deviations of these elements.

4. Procedure and Methodology

The participants reported ARL Robotics test facility at APG to begin study participation. As part of the pre-test procedure, participants were given a volunteer agreement affidavit describing the study and possible risks, during which time all questions pertaining to the study were addressed. Prior to experimentation, participants were tested for visual acuity using a Titmus II vision-testing device. Demographic data was also collected at this time. All participants were familiarized with the workload, motion sickness (MSAQ), and control/display rating questionnaires (MCH-UVD) immediately following visual screening and demographic data collection. This was followed by several days of participant training on the teleoperated system in both control modes under day and night conditions.

Participants received 3 days of system training from system vendors with a total of 12-h operation time teleoperating the system from qualified system trainers. This training occurred immediately prior to experimental data collection which followed training.

4.1 Participant Scenario

System familiarization was given to each participant prior to the study to ensure that proper and safe operation of the system would be performed. Participants were assigned to their subject identification numbers and subsequent condition orders prior to the experimental data collection day. The order of presentation conditions is presented in tables 1 and 2.

Table 1. Day – trial presentation order.

	Trial					
	1	**2**	**3**	**4**	**5**	**6**
TP1	M8	M15	T8	T15	TC8	TC15
TP2	M15	T15	TC15	T5	M8	TC8
TP3	T8	TC15	TC8	M8	M15	T15
TP4	T15	TC8	M8	M15	TC15	T8

Note: M = Manned, T = Teleoperated, TC = Teleoperated Cruise Control, 8 = 8 mph, and 15 = 15 mph.

Table 2. Night – trial presentation order.

	Trial					
	1	**2**	**3**	**4**	**5**	**6**
TP1	TC8	M8	T15	TC15	T8	M15
TP2	TC15	TC8	T15	T8	M15	M8
TP3	M8	M15	T8	T15	TC8	TC15
TP4	M15	T15	TC15	T5	M8	TC8

Note: M = Manned, T = Teleoperated, TC = Teleoperated Cruise Control, 8 = 8 mph, and 15 = 15 mph.

At the experimental test site, participants were given additional training and familiarization with the remote control modes by operating up to two laps around the test course. For each test condition, the participants drove for four laps as accurately as they could while attempting to maintain the designated speed using their visual display to track the vehicle with the road center. All steering, braking, and throttle controls were performed with the hands using the steering wheel or controls located on the steering wheel. After four laps, the participants were asked to rate their workload by assessing several workload subscales, their motion sickness with the MSAQ, and their quality ratings of the controls and displays with the Modified Cooper-Harper Scale. Test participants were then fully debriefed and given a point of contact for follow-up on individual performance or results of the study. All participants in this study were exposed to all control modes. Following the study, test participants' motion sickness was assessed to determine if they should remain at the facility due to these effects. None of the four test participants exhibited even mild effects of motion sickness following the study.

5. Results

Two separate 3 × 2 factorial repeated measures ANOVAs were used to examine the main effects of control mode and speed, and the possible interaction effects among mode and speed for all dependent measures (alpha = 0.05 significance level), including lateral drift from the center of the lane (in), road edge crossing errors, workload ratings, and motion sickness. These two separate analyses were performed for separate day and night conditions. Tukey's LSD was used as a post-hoc analysis to perform pair-wise comparisons between treatment cells. Day and night conditions were analyzed separately due to the change in visual sensors for day and night operation.

5.1 Day-Time Analyses

The results for lateral drift data yielded significant results for the effect of speed, $F(1,3) = 16.38$, $p = 0.027$, and $\eta 2 = 0.845$. The effect size was very large accounting for 84.5% of the variance. The lateral drift means for each condition with associated standard error bars are presented in figure 2. The main effect for mode and the interaction were both non-significant. The results for road edge crossing error data yielded significant results for the effect of speed, $F(1,3) = 13.34$, $p = 0.035$, and $\eta 2 = 0.816$. The effect size was very large accounting for 81.6% of the variance. The road-edge crossing error means for each condition with associated standard error bars are presented in figure 3. The main effect for mode and the interaction were both non-significant.

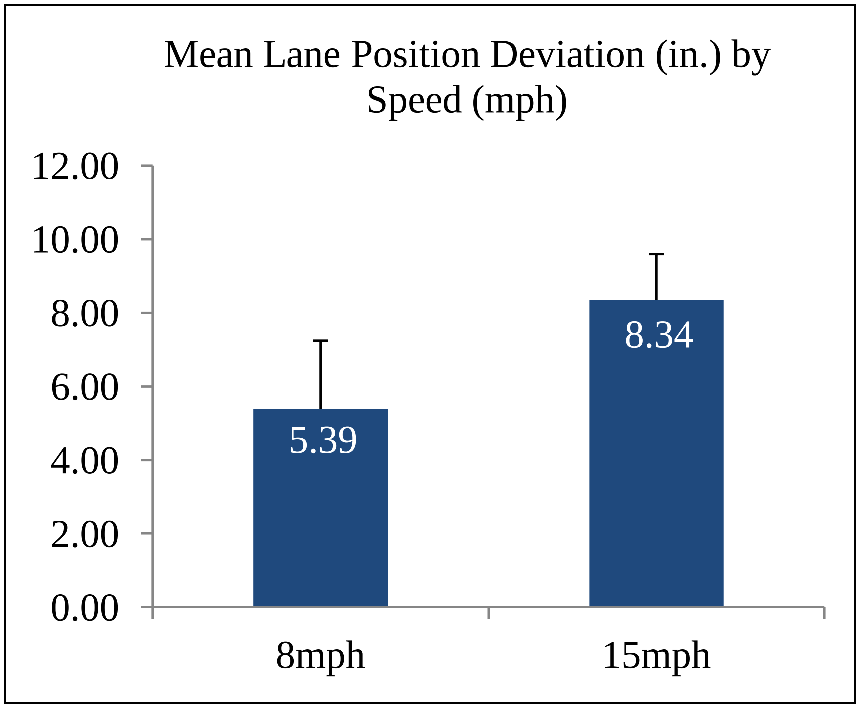

Figure 2. Mean lane-position deviation (in) by speed (mph) – day operation.

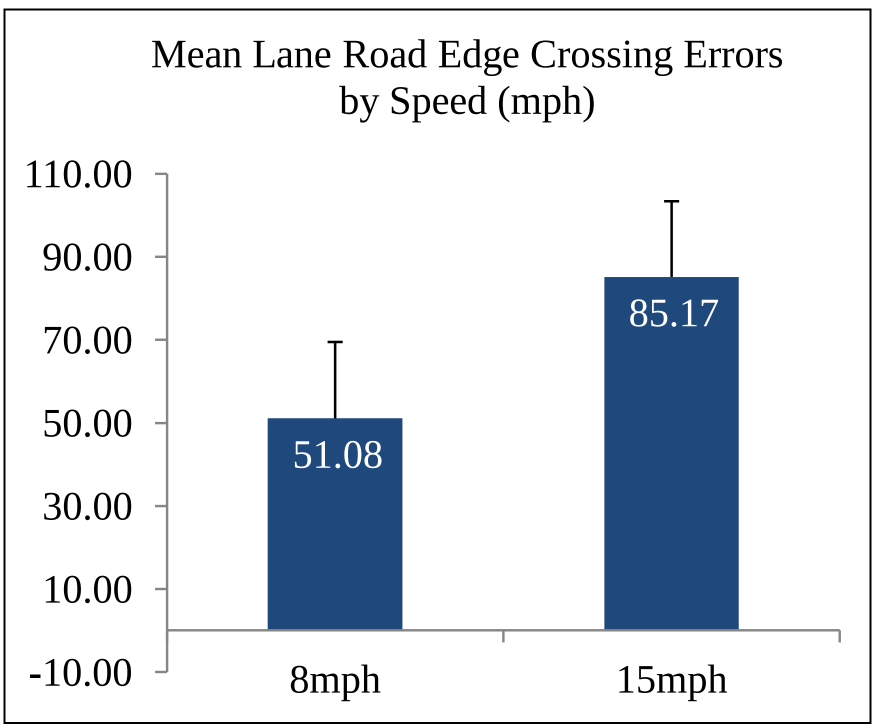

Figure 3. Mean lane road-edge crossing errors by speed (mph) – day operation.

Results for workload ratings demonstrated a nearly significant effect for mode, $F(2,6) = 4.32$, $p = 0.069$, and $\eta 2 = 0.590$. The effect size was moderate, accounting for 59.0% of the variance. Though non-significant at the p = 0.05 alpha level, the explained variance is considerable and the workload means for each condition with associated standard error bars are presented in figure 4. The main effect for mode and the interaction were both non-significant. The Tukey's LSD post-hoc test revealed that the differences were due to cell differences between the teleoperation-only and teleoperation-cruise control modes.

The results for motion sickness ratings revealed non-significant results for the effect of speed, $F(1,3) = 6.99$, $p = 0.077$, and $\eta 2 = 0.700$. The effect size was very large, accounting for 70.0% of the variance. Though non-significant at the p = 0.05 alpha level, the explained variance is considerable with reasonably high power. The main effect for mode and the interaction effect were also both non-significant.

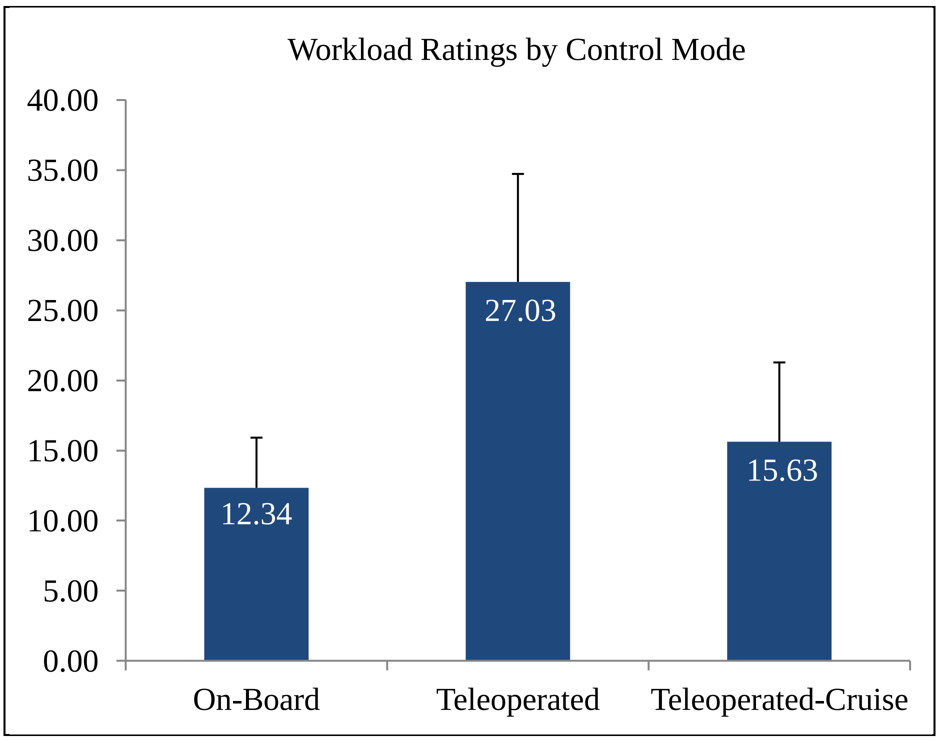

Figure 4. Overall workload ratings by control mode – day operation.

These results are astounding considering the extremely small sample size ($n = 4$) and the moderate and large effect sizes revealed. The results reflected an increased lateral drift away from the road center under the higher speed of 15 mph as compared to 8 mph, as collapsed across all conditions. A summary of all ANOVA data is presented in table 3.

Table 3. Daytime ANOVA table of dependant measures.

Lateral Drift (in.)	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	14.59	2	7.30	0.523	0.618	0.148	0.10
Speed	52.42	1	52.42	16.38	**0.027**	**0.845**	0.76
Mode × speed	7.34	2	3.67	1.02	0.42	0.253	0.16
Road Edge Error	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	2000.25	2	1000.12	0.84	0.478	0.208	0.14
Speed	6970.04	1	6970.04	13.34	**0.035**	**0.816**	0.69
Mode × speed	196.08	2	98.04	0.40	0.69	0.117	0.09
Workload	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	950.91	2	475.45	4.32	0.069	0.590	0.44
Speed	4.16	1	4.16	0.86	0.42	0.222	0.10
Mode × speed	11.89	2	5.92	0.39	0.69	0.115	0.09
Motion Sickness	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	18.25	2	9.12	0.92	0.45	0.234	0.14
Speed	1.04	1	1.04	6.99	0.077	0.700	0.70
Mode × speed	20.58	2	10.29	2.01	0.22	0.401	0.27

5.2 Night-Time Analyses

The results for lateral drift data yielded significant results for the main effects of speed, $F(1,3) = 47.87$, $p = 0.006$, and $\eta 2 = 0.941$. The effect size was very large accounting for 94.1% of the variance. The lateral drift means for each condition with associated standard error bars are presented in figure 5. The main effect for mode and the interaction were both non-significant.

The results for road edge crossing error data yielded significant results for the main effects of speed, $F(1,3) = 85.47$, $p = 0.003$, and $\eta 2 = 0.966$, and mode, $F\ (2, 6) = 8.67$ and $p = 017$. The effect size for this result was $\eta_p^2 = 0.743$, with the mode treatment accounting for 74.3% of the variance, a very large treatment effect. The road edge crossing error means for each condition with associated standard error bars for the effects of speed and mode are presented in figures 6 and 7, respectively. The interaction was non-significant. The post-hoc analysis for road-edge crossing errors revealed that on-board driving was different from teleoperation-only and that teleoperation-only was different from teleoperation with cruise control.

The results for workload ratings demonstrated a significant finding for the main effect of mode, $F(2,6) = 5.10$, $p = 0.05$, and $\eta 2 = 0.630$. The effect size was large, accounting for 63.0% of the variance. The workload rating means for each condition with associated standard error bars are presented in figure 8. The main effect for speed and the interaction effect were both non-significant. The Tukey's LSD post-hoc for mode test revealed that the differences were due to cell differences between the teleoperation-only and teleoperation-cruise control modes as well as a nearly significant difference between manual driving and teleoperation-only mode.

The results for motion sickness ratings revealed no significant differences for either the main effects or the interaction. A summary of all ANOVA data is presented in table 4.

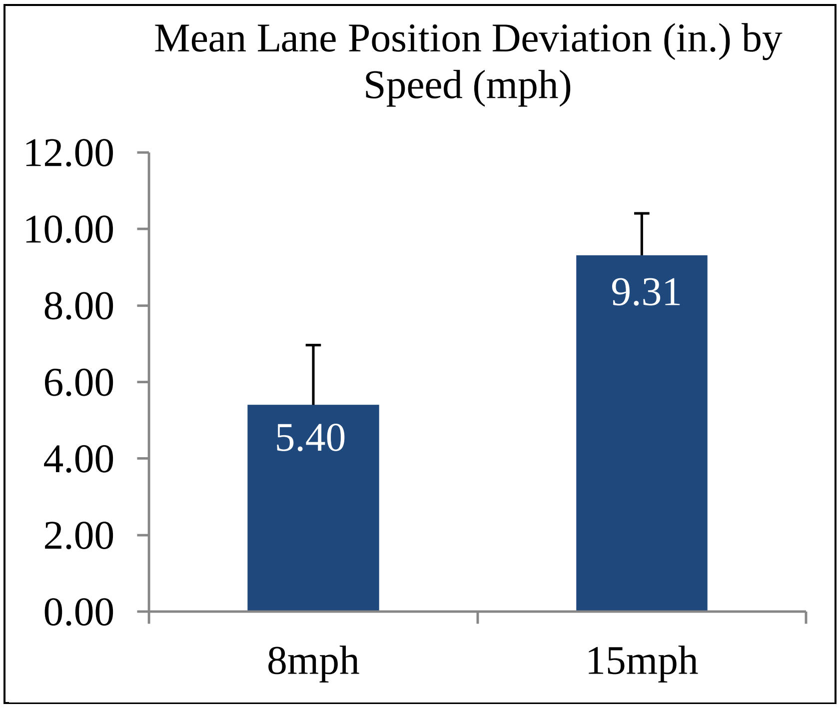

Figure 5. Mean lane-position deviation (in) by speed (mph) – night operation.

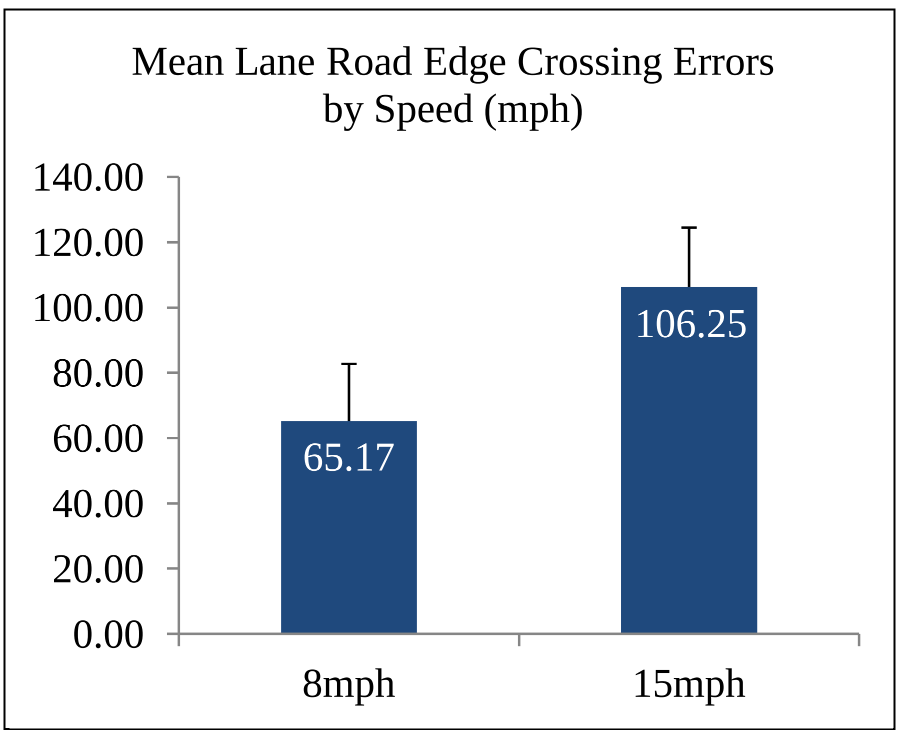

Figure 6. Mean lane road-edge crossing errors by speed (mph) – night operation.

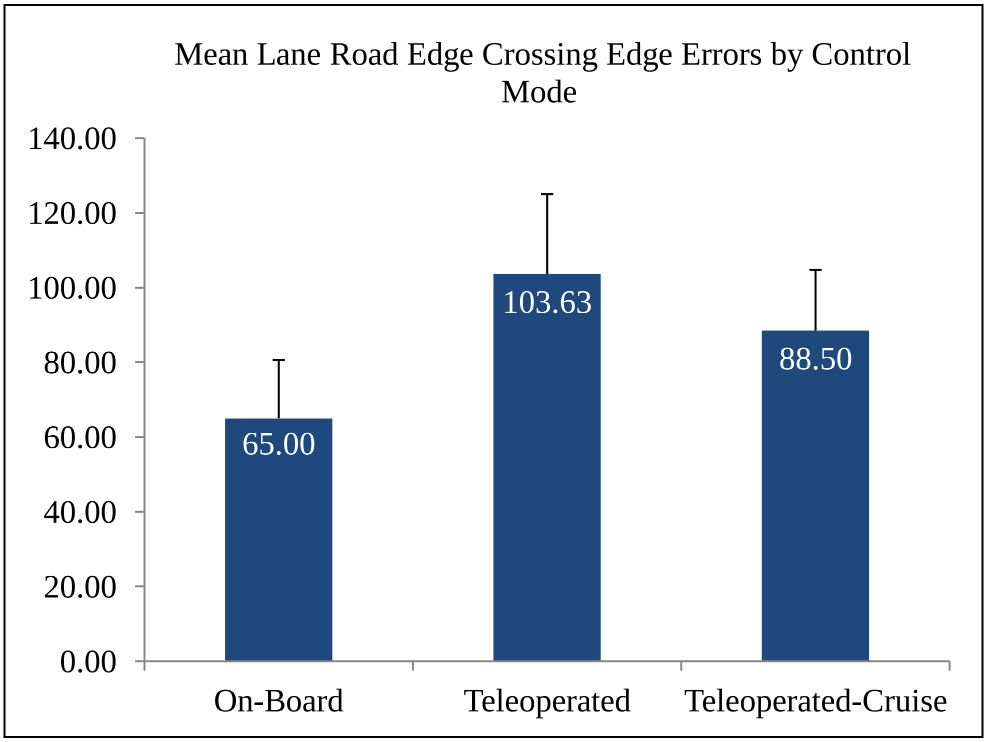

Figure 7. Mean lane road-edge crossing errors by control mode – night operation.

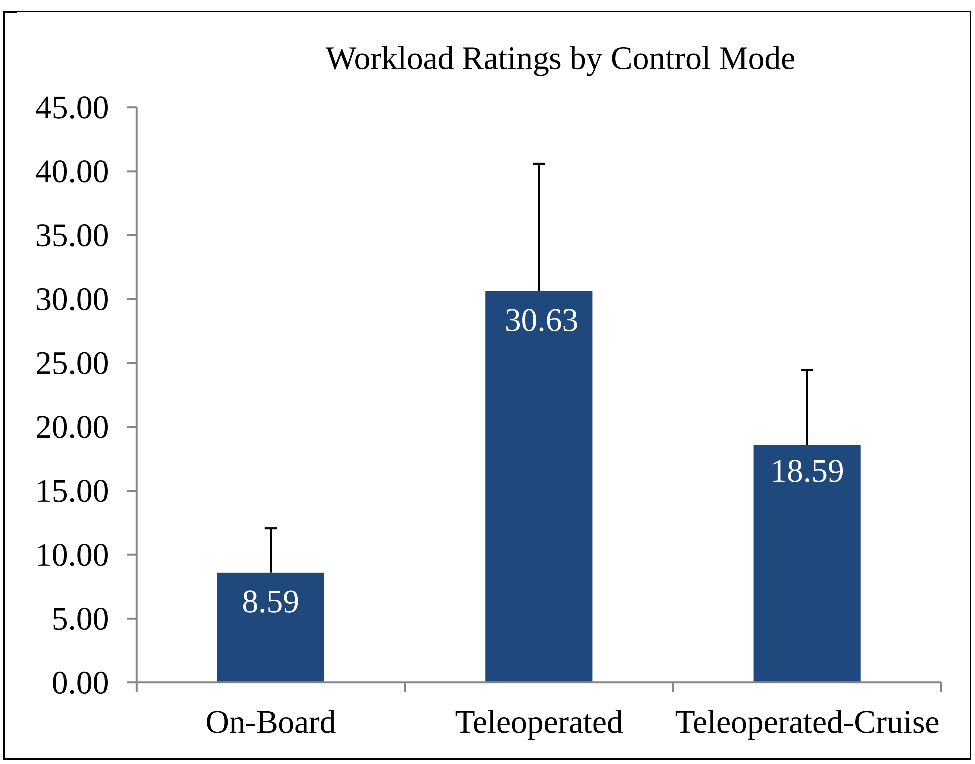

Figure 8. Workload ratings by control mode – night operation.

Table 4. Nighttime ANOVA table of dependant measures.

Lateral Drift (in.)	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	2.94	2	1.47	0.21	0.81	0.067	0.07
Speed	91.96	1	91.96	47.87	**0.006**	**0.941**	0.99
Mode × speed	2.17	2	1.08	1.30	0.34	0.302	0.19
Road-Edge Error	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	6061.08	2	3030.54	8.67	**0.017**	**0.743**	0.82
Speed	10127.04	1	10127.04	85.47	**0.003**	**0.966**	1.00
Mode × speed	144.08	2	72.04	0.34	0.73	0.101	0.08
Workload	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	1947.00	2	973.50	5.10	**0.05**	**0.630**	0.59
Speed	75.26	1	75.26	1.92	0.26	0.391	0.16
Mode × speed	25.13	2	12.56	0.78	0.49	0.207	0.13
Motion Sickness	**SS**	**df**	**MS**	**F**	**Sig.**	**Eta^2**	**Power**
Mode	21.58	2	10.79	2.12	0.20	0.415	0.28
Speed	3.37	1	3.37	0.75	0.45	0.200	0.10
Mode × speed	0.75	2	0.38	0.57	0.59	0.161	0.11

5.3 Control and Display Ratings

Control and display ratings were derived from responses taken using an MCH scale (Cummings et al., 2006). The lowest score, 1, represents a very good rating requiring no change; 10 indicates an item that requires complete redesign. It can be noted that the ratings for all items usually differed the most between on-board driving and teleoperated conditions. There were some differences that were due to the change between teleoperated and teleoperated and cruise control conditions. Most of the increased scores were in the range of “minor but tolerable” to moderately objectionable deficiencies. Anecdotally, the Soldiers who used this system stated that they often felt fatigued in their hands and forearms after about a 30-min operational period. This was due to the dual function of the hand-grasp around the steering wheel: to steer the vehicle and to adjust speed with brake and accelerator controls that were grasp-oriented on the steering wheel. The brake and accelerator paddles can be observed in figure 1.

Table 5. Mean (M) and standard deviation (SD) for control and display ratings (N = 4) by mode and speed – day operations.

	Day				
	Mode			**Speed**	
	Onboard	**Teleop**	**Teleop-Cruise**	**8 mph**	**15 mph**
Controls					
Steering	1.38, 0.5	2.13, 0.9	2.00, 0.7	1.83, .08	1.83, 0.8
Accelerator	1.25, 0.5	3.88, 1.8	2.63, 1.3	2.58, 1.7	2.58, 1.7
Brake	1.50, 0.5	3.38, 2.1	2.38, 1.4	2.42, 1.7	2.42, 1.7
Displays					
Video	2.00, 1.9	2.38, 0.5	1.88, 0.6	2.17, 1.2	2.00, 1.1
Speedometer	1.50, 0.7	3.00, 1.1	2.25, 1.0	2.33, 1.2	2.17, 1.1

Table 6. Mean (M) and standard deviation (SD) for control and display ratings (N = 4) by mode and speed – night operations.

	Night				
	Mode			**Speed**	
	Onboard	**Teleop**	**Teleop-Cruise**	**8 mph**	**15 mph**
Controls					
Steering	1.25, 0.5	1.75, 0.9	1.88, 0.8	1.58, 0.8	1.67, 0.8
Accelerator	1.25, 0.5	3.38, 1.4	3.13, 1.5	2.67, 1.6	2.50, 1.5
Brake	1.50, 0.5	3.00, 1.5	3.13, 1.5	2.50, 1.5	2.58, 1.4
Displays					
Video	1.75, 1.5	2.38, 1.4	2.25, 1.2	2.00, 1.2	2.25, 1.3
Speedometer	1.50, 0.9	2.63, 1.4	2.25, 1.2	2.17, 1.2	2.08, 1.3

6. Discussion

Differences were revealed for the effect of vehicle speed only under day conditions. However, independent variables for both control mode and vehicle speed yielded significant differences among the treatment groups for performance measures and workload ratings under nighttime conditions. The daytime results highlighted the effects of vehicle speed differences but revealed no significant results for control mode, which was the primary variable of interest.

The sample size of this study must be highlighted as a potential shortfall of this study. Many logistical and administrative issues arose prior to imminent data collection that reduced an already small sample size to that what was reported in this study (n = 4). However, when the data were analyzed, moderate-to-strong effect sizes in combination with the significant or nearly significant findings made the data worth reporting.

The hypothesis regarding performance differences for the effect control mode was not supported through the daytime operation results, however, nighttime results countered this effect with a profoundly stronger treatment effect and higher resultant statistical power. The bulk of the findings for objective performance data (lane-position deviation and lane edge errors) were significant for the main effect of vehicle speed only, which seems to be a natural phenomenon for almost any driven system with a less-than-perfect control-display system. Workload, however, did show meaningful differences among control modes that support results found in previous teleoperation research work by Scribner and Dahn (2008). These differences reflected a relatively low workload for manned driving in comparison to the approximate doubling of perceived cognitive workload for the teleoperation mode. Cognitive workload subsided significantly when the task of speed control was removed from the teleoperation-cruise control mode. As for motion sickness scores under day conditions, no statistical or practical significance was observed.

The first hypothesis is considered supported by virtue of the night operation data, which in this case provided findings with high effect sizes, accounting for a large portion of the explained variance. Night operation yielded significant findings for the main effects of control mode and vehicle speed, demonstrating that either visual sensors and displays or ambient illumination or a combination of both affected these treatment conditions significantly. Significant differences for the effect of speed were demonstrated in the dependent task performance measures of lane position deviation and lane-edge errors as well as for cognitive workload. No differences were noted for motion sickness. The lane-edge errors were significant for both main effects of control mode and vehicle speed. Lane-edge errors paralleled the outcomes for cognitive workload differences as there was an increase of about 58% error from manned operation to teleoperated conditions. Teleoperated-cruise control conditions yielded a lower lane-edge error rate as compared to teleoperated operation. This error rate was less at 35% in comparison to manned driving. This data is supported by similar findings by Scribner and Dahn (2008).

Night conditions for driving using the night sensor and display system in particular had a noticeable treatment-enhancing effect, thus drastically increasing the statistical power and associated treatment effect sizes that are reported in tables 3 and 4. This is apparent for the number of significant and nearly significant findings for task performance measures of lane-edge errors and for cognitive workload measures.

Workload measures as reported by the modified NASA-TLX indicated that control mode was a nearly significant and significant measure for both day and night conditions, respectively. Night conditions again seemed to have put more treatment pressure on the Soldier system, creating greater treatment effect sizes, power values, and significance levels for this dependent measure. Under night conditions, all three control modes were significantly different from each other, with associated elevated subjective workload for teleoperated-cruise control over manual driving and teleoperated driving over the other two operation conditions (figure 8).

The second hypothesis is considered empirically supported with data that demonstrated findings with a large treatment effect size, accounting for a large portion of the explained variance. The second hypothesis of superior performance for the manned mode was also supported by the data, as the subjective workload for manned operation mode was far lower than the two teleoperated modes. This data supports the previous work of Dixon et al. (2003), Scribner and Dahn (2008), and Schipani (2003), who demonstrated that workload is increased for higher levels of operator involvement, to include teleoperators and robotics control. The general notion that teleoperated and robotic systems have reduced sensory and situational information available and uncoupled motion effects is supported in the general literature review findings cited by Chen et al. (2007).

Motion sickness findings were non-significant and are considered unsupported by the evidence within this study. This finding is consistent with speed-related motion sickness results found in an unpublished report by Scribner (2008), who found that teleoperators operating from a moving HMMWV-based platform reported little-to-no motion sickness at slow speeds of 5–15 mph but showed marked and significant increase in motion sickness in speed bands from 25 to 35 mph, and further still for speeds of 35 mph and higher. There were no night condition results of any value for motion sickness in this unpublished study. The lack of significant motion sickness findings is attributed to the benign nature of operating on a relatively stable test course at what are considered low speeds and the data cannot support nor refute previous motion sickness findings (Cowings et al., 1999; Hill and Tauson 2005; Kamsickas, 2003; Schipani, 2003; Scribner, 2008).

Control and display ratings were quite interesting in two regards. First, these ratings were apparently susceptible to change by both vehicle speed and control mode treatments. In all cases, the control ratings for the accelerator and brake (hand controls used in this study's teleoperation modes) were rated poorer for both teleoperated conditions than for standard controls found in the HMMWV. This effect was magnified somewhat under night conditions. For example, the throttle control quality was rated to be significantly poorer for both teleoperated conditions during the day. At night, steering, throttle, video display, and speedometer ratings were all rated poorer under both teleoperation modes. See tables 3 and 4 for results.

7. Conclusions

The data seem to indicate that the best teleoperated condition for operator involvement with simultaneous secondary tasks would be the teleoperated-cruise control condition due to the significantly lowered workload and increased performance compared to teleoperation without cruise control. The data indicate that if a Soldier is best removed from danger via remote control technology, then teleoperated missions should be performed in teleoperation with cruise control mode. The measures for this control mode had less lateral drift error (vehicle swerve), off-road misses (lane-displacement errors), and lowered subjective cognitive workload.

Controls and displays should be assessed to determine what form and function changes would be beneficial to operator comfort and endurance. Test participants commented that the combined steering-throttle-brake system was good, but that arm rests would greatly reduce the musculo-skeletal fatigue experienced in the forearms and hands while operating in teleoperated mode. The dead-man switches (spring return safety mechanisms to return to zero input) for the brake and accelerator controls created muscular fatigue as reported by a majority of the test participants. Force required to operate these controls could be greatly reduced while still having spring return qualities if released.

Motion sickness data in this study were non-significant due to the low-speed operations of the system. With other tested teleoperated systems, motion sickness appears to have significant effects in speed bands beyond 15 mph (Scribner, 2008).

The control lag within the system assessed was not truly noticeable to the operators and was not considered a significant factor contributing to dependent variable differences in control mode.

The speeds of operation in this study can be considered “benign” under daytime conditions, which revealed no significant differences. However, night conditions, under which many Soldier systems operate in today’s operational theatres, revealed significant differences in control mode for lane-edge contact errors and cognitive workload. It should be noted that night conditions may increase treatment effect sizes and statistical power when conducting future teleoperated systems experiments. The differences found in this research are best attributed to reduced sensory information availability paired with slight uncoupled motion effects.

In furthering research of this type, it would be recommended that the number of available test participants be increased to allow sufficient statistical power under day conditions if a system is to be operational in this condition. Additionally, extended and more realistic operational scenarios employing up to two hours of continuous operations under day and night operations should be considered. If safety strictures allow, it is proposed that workload, vigilance, and fatigue difference effects for various control modes would be greatly enhanced under these conditions. These suggestions would reveal important human factors engineering (HFE) aspects that can be countered with improved HFE design suggestions to prolong mission scenario engagement, reduce workload and stress, and that increase Soldier combat performance and comfort within such systems.

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Appendix A. Volunteer Agreement Affidavit

This appendix appears in its original format, without editorial change.

VOLUNTEER AGREEMENT AFFIDAVIT:

ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponent for this research is:	**U.S. Army Research Laboratory** **Human Research and Engineering Directorate** **Aberdeen Proving Ground, MD 21005**

Authority:	Privacy Act of 1974, 10 U.S.C. 3013, [Subject to the authority, direction, and control of the Secretary of Defense and subject to the provisions of chapter 6 of this title, the Secretary of the Army is responsible for, and has the authority necessary to conduct, all affairs of the Department of the Army, including the following functions: (4) Equipping (including research and development), 44 USC 3101 [The head of each Federal agency shall make and preserve records containing adequate and proper documentation of the organization, functions, policies, decisions, procedures, and essential transactions of the agency and designed to furnish the information necessary to protect the legal and financial rights of the Government and of persons directly affected by the agency's activities]
Principal purpose:	To document voluntary participation in the Research program.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects

Note: Volunteers are authorized medical care for any injury or disease that is the direct result of

participating in this project (under the provisions of AR 40-38 and AR 70-25).

Part B • To be completed by the Principal Investigator

Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with
Appendix C, AR 40-38 or AR 70-25.

Purpose of the Research

Title of Research Project:	**1.** A Comparison of Soldier Performance in a Moving Command Vehicle Under Manned, Teleoperated and Semi-Autonomous Robotic Mine Detector System Control Modes.	
Human Use Protocol Log # Number:	**ARL-20098-09008**	
Principal Investigator:	David Scribner	Phone: 410-278-5983 email: david.scribner@us.army.mil
Associate Investigators:	Asi Animashaun Will Culbertson	410-278-5883, aanimashaun@arl.army.mil 254-288-9222, will.culbertson@us.army.mil
Location of Research:	Aberdeen Proving Ground, MD	
Dates of Participation:	March-October 2009	

You are invited to participate in a study designed to evaluate the effects of different road surfaces and speeds on remote control vehicle performance. More specifically, the purpose of this study is to compare three different speeds of control and their effects on route path quality, course time, and ratings of mental effort, motion sickness, stress, and vehicle controllability. This study will be conducted the Aberdeen Test Center (ATC) test courses at Aberdeen Proving Ground, Maryland.

Procedures

Participation in this study will require two weeks of visitation to the test course facility at APG, MD. On the first day, you will be asked to (1) provide written informed consent to participate in the study, (2) choose whether or not to provide the principle investigator your ASVAB scores (3) be assigned a confidential participant ID number, (4) complete a demographics questionnaire, and (5) be tested for visual acuity and color vision. After this, you will be familiarized with the teleoperated system, the test courses, and safety procedures pertaining to the operation of the system. You will train for several days at the beginning of the first week on how to specifically operate the teleoperated and manned systems. During the second week, you will be exposed to twelve experimental trials, combinations of manned/unmanned operation, maximum speed, and time of operation (day or night camera). Following this, you will be de-briefed and given information on how to contact the researcher for questions that you may have about your data or the study after it is complete. Your time commitment in this study will be approximately from 0800-1700 with a one-hour break for lunch. During night trials, your time commitment will be approximately from 1800-0200 with a one-hour break for eating or rest after four hours.

There is a risk of motion sickness in this study, as you will be moving in a vehicle that follows the teleoperated vehicle, at speeds up to but not exceeding 25 mph. This is considered a safe speed, which may generate incapacitating motion sickness. You are free to withdraw from this study at any time for any reason, including feeling any effects of motion sickness. You will be operating inside of a vehicle that will be heated and provide shelter from weather effects such as wind and precipitation. You will be asked to wear a seat belt at all times when operating the vehicle. You will also be asked to wear a safety helmet for protection when inside the control vehicle.

You will be asked to complete questionnaires relating to workload, stress, and motion sickness at mid-completion and at the end after each experimental trial. You will also be asked to fill out a baseline motion sickness questionnaire. The test course you will operate the vehicle on is approximately 4800 meters in length. You will operate one lap in one direction and then another lap in the opposite direction. One run will be about a half-hour long. You will be permitted to have a break for 30 minutes between trials. This will require approximately 6 hours of experimental teleoperation in all, not including training. You may not be eligible to participate in this study if: (1) your visual acuity is less than 20/30 when corrected with glasses or contact lenses, or if 2) your medical profile indicates that your health status requires approval by your physician.

Benefits

You will receive no benefits from participating in the project, other than the personal satisfaction of supporting research efforts to better understand factors that affect differences in various remote control modes for teleoperated mine detection systems.

Risks

Risks associated with this evaluation are minimal and are less than those encountered by Soldiers during their normal field training exercises or by civilians driving on public roads. There is a moderate risk of motion sickness and steps will be taken to prepare for this possibility. These steps include having a motion sickness bag and pre-soaked sterile wipes and hand sanitizer available in case of vomiting. There will also be refreshments offered and a place to sit comfortably or lie down for any time period required. If you develop motion sickness symptoms, we will ask you to remain at the site until symptoms disappear.

Members of the test administration staff will be close to you throughout all evaluation trials to assist you should a problem arise. If you ask to terminate the test, care will be taken to minimize risks and you will be allowed to cease participation. You will have a break of at least 10 minutes lasting up to 30 minutes between conditions.

Confidentiality

All data and information obtained about you will be considered privileged and held in confidence. We would like your permission to take photos and audio/video recording of you during your experimental runs. The photos will be used for presentation and a final report. The video may be used for a briefing on the experiment. The photos will have your face and name blurred to obscure identifying information. Video footage will be taken at such an angle that you will not be able to be positively identified. Complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Human Research Protection Office officials may inspect the records. Please indicate below if you will agree to allow us to record you. You can still be in the study if you prefer not to be recorded.

I give consent to being audio taped during this study ____YES ____NO please initial____

I give consent to being videotaped during this study ____YES ____NO please initial____

I give consent to being photographed during this study ____YES ____NO please initial____

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The Principal Investigator will provide a copy of the signed and initialed Affidavit to you.

Obtaining of ASVAB Scores

IF YOU ARE AN ACTIVE DUTY ENLISTED MILITARY VOLUNTEER, we would like to obtain your Armed Services Vocational Aptitude Battery (ASVAB) scores for potential data analysis. The ASVAB scores would be used strictly for research purposes. The results of any such analyses would be presented for the group of participants as a whole; and no names will be used. With your permission, we will obtain these scores by sending a copy of this signed consent form along with your Social Security Number to the Defense Manpower Data Center (DMDC) in Seaside, CA where ASVAB scores may be obtained from their databases in Arlington, VA or Seaside, CA. If you do not wish your ASVAB scores to be released to the principal investigator, you will still be allowed to participate in the research.

If you would like to participate in this research, please sign one of the following statements, and then complete the information requested at the end of this form:

I **DO AUTHORIZE** you to obtain my ASVAB scores. ______________________________
(Your Signature)

I **DO NOT AUTHORIZE** you to obtain my ASVAB scores.

____
(Your Signature)

Contacts for Additional Assistance

If you have questions concerning your rights on research-related injury, or if you have any complaints about your treatment while participating in this research, you can contact:

Chair, Human Use Committee	**OR**	**Office of the Chief Counsel**
U.S. Army Research Laboratory		**U.S. Army Research Laboratory**
Human Research and Engineering Directorate		**2800 Powder Mill Road**
Aberdeen Proving Ground, MD 21005		**Adelphi, MD 20783-1197**

(410) 278-5992 or (DSN) 298-5992 **(301) 394-1070 or (DSN) 290-1070**

I do hereby volunteer to participate in the research project described in this document. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research project, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or project related injury, I may contact the **ARL-HRED Human Use Committee Chairperson at Aberdeen Proving Ground, Maryland, USA by telephone at 410-278-5992 or DSN 298-5992.** I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty. I understand that military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human volunteers and that no administrative sanctions can be given me for choosing not to participate. I may at any time during the course of the project revoke my consent and withdraw without penalty or loss of benefits. However, I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of an attending physician, such examinations are necessary for my health and well being.

<table>
<tr><td colspan="2">***Printed Name Of Volunteer (First, MI., Last)***</td></tr>
<tr><td>***Social Security Number (SSN)***</td><td rowspan="2">***Permanent Address Of Volunteer***</td></tr>
<tr><td>***Date Of Birth (Month, Day, Year)***</td></tr>
<tr><td>***Today's Date (Month, Day, Year)***</td><td>***Signature Of Volunteer***</td></tr>
<tr><td colspan="2">***Signature Of Administrator***</td></tr>
</table>

Appendix B. Demographic Data Collection Form

This appendix appears in its original form, without editorial change.

DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE Soldier ID ___

Age_____ Height ___ ft ___ in Weight _____lbs

Rank______ Date entered military (month)_______ (year)______

Date Armed Services Vocational Aptitude Battery (ASVAB) taken (month)_____
(Year)_____N/A_____

If applicable, Primary MOS______ Secondary MOS______ OR Job
Title____

1. Have you operated a remote military system before? ____Yes ____No

2. Have you operated radio-controlled hobby systems before? (Car, plane) ____Yes ____No

3. How well do you feel you perform with remote vehicles?

____Poor ____Below Average ____Average ____Above Average ____Excellent

4. Does your Military Occupational Specialty include driving any vehicles? ____Yes ____No

5. Are you ____left handed or ____right handed?

6. Do you use your ____left eye or ____right eye to aim a weapon?

7. Do you wear glasses/contact lenses when you drive ? ___ Yes ___ No

8. a. Do you play video games or computer games? ___Yes ___No

b. What type of specific systems do you use? ___ Console ____ PC ____Both

9. Do you ever play simulations or games that have driving involved? ____Yes ____No

10. How well do you think you play driving video games?
____Poor ____Below Average ____Average ____Above Average ____Excellent

11. What is your current education level?

____High School ____Junior College ____Bachelor’s Degree ____MA ____PhD

12. How susceptible are you to motion sickness? ___Low ___Moderate ____ high

---

Vision Testing Score: (Acuity)____________________________ (Color Vision)_________

Appendix C. Modified NASA Task Load Index (M-NTLX)

This appendix appears in its original form, without editorial change.

NASA-TLX Workload Questionnaire (Weighting Selection)

Soldier ID_________
Date___/___/___

(one time only, per test participant)

For each pair, select the one element that is more important for measurement of workload for the task.

☐	Mental Demand	/	Physical Demand	☐
☐	Mental Demand	/	Temporal Demand	☐
☐	Physical Demand	/	Temporal Demand	☐

NASA-TLX RATING SCALE DEFINITIONS

MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*L o w/High*	How much physical activity was required (e.g.. pushing, pulling, turning, controlling, activating,, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous restful or laborious?
TEMPORAL DEMAND	*L o* w/Hig*h*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

NASA-TLX Workload Questionnaire (Weighting Selection)

Soldier ID_______________
Date___________________
Condition_______________

For each workload element listed below, please indicate (with an exact mark on the line) how much each element contributed to your overall workload experienced in the task you just performed. Please write the corresponding number for your mark in the space provided below each line.

Mental Workload
0 — 100
Low — High
What number is this?_____

Physical demand
0 — 100
Low — High
What number is this?_____

Temporal Demand
0 — 100
Low — High
What number is this?_____

INTENTIONALLY LEFT BLANK.

Appendix D. Motion Sickness Assessment Questionnaire (MSAQ) Form

This appendix appears in its original form, without editorial change.

Motion Sickness Assessment Questionnaire

Soldier ID ________________

Date _____________________

Condition:_________________

Using the scale below, please circle the number that rates how accurately the following statements describe your experience.

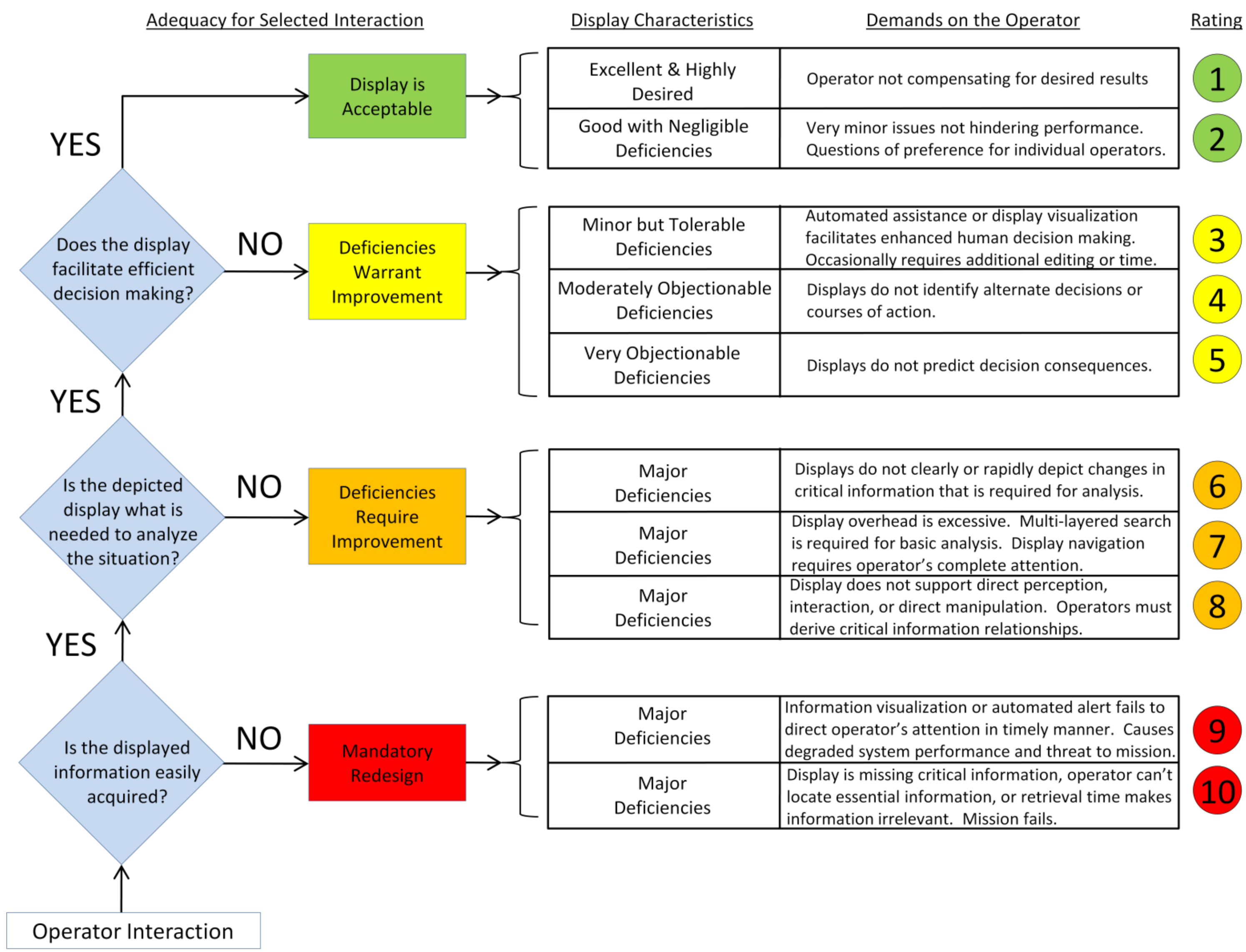
	Not at all — Severely
1. I felt sick to my stomach	1-------2-------3-------4-------5-------6-------7-------8-------9
2. I felt faint-like	1-------2-------3-------4-------5-------6-------7-------8-------9
3. I felt annoyed / irritated	1-------2-------3-------4-------5-------6-------7-------8-------9
4. I felt sweaty	1-------2-------3-------4-------5-------6-------7-------8-------9
5. I felt queasy	1-------2-------3-------4-------5-------6-------7-------8-------9
6. I felt lightheaded	1-------2-------3-------4-------5-------6-------7-------8-------9
7. I felt drowsy	1-------2-------3-------4-------5-------6-------7-------8-------9
8. I felt clammy / cold sweat	1-------2-------3-------4-------5-------6-------7-------8-------9
9. I felt disoriented	1-------2-------3-------4-------5-------6-------7-------8-------9
10. I felt tired / fatigued	1-------2-------3-------4-------5-------6-------7-------8-------9
11. I felt nauseated	1-------2-------3-------4-------5-------6-------7-------8-------9
12. I felt hot / warm	1-------2-------3-------4-------5-------6-------7-------8-------9
13. I felt dizzy	1-------2-------3-------4-------5-------6-------7-------8-------9
14. I felt like I was spinning	1-------2-------3-------4-------5-------6-------7-------8-------9
15. I felt as if I may vomit	1-------2-------3-------4-------5-------6-------7-------8-------9
16. I felt uneasy	1-------2-------3-------4-------5-------6-------7-------8-------9

17. How many times have you vomited today? _________

Appendix E. Modified Cooper-Harper Display Ratings Form

This appendix appears in its original form, without editorial change.

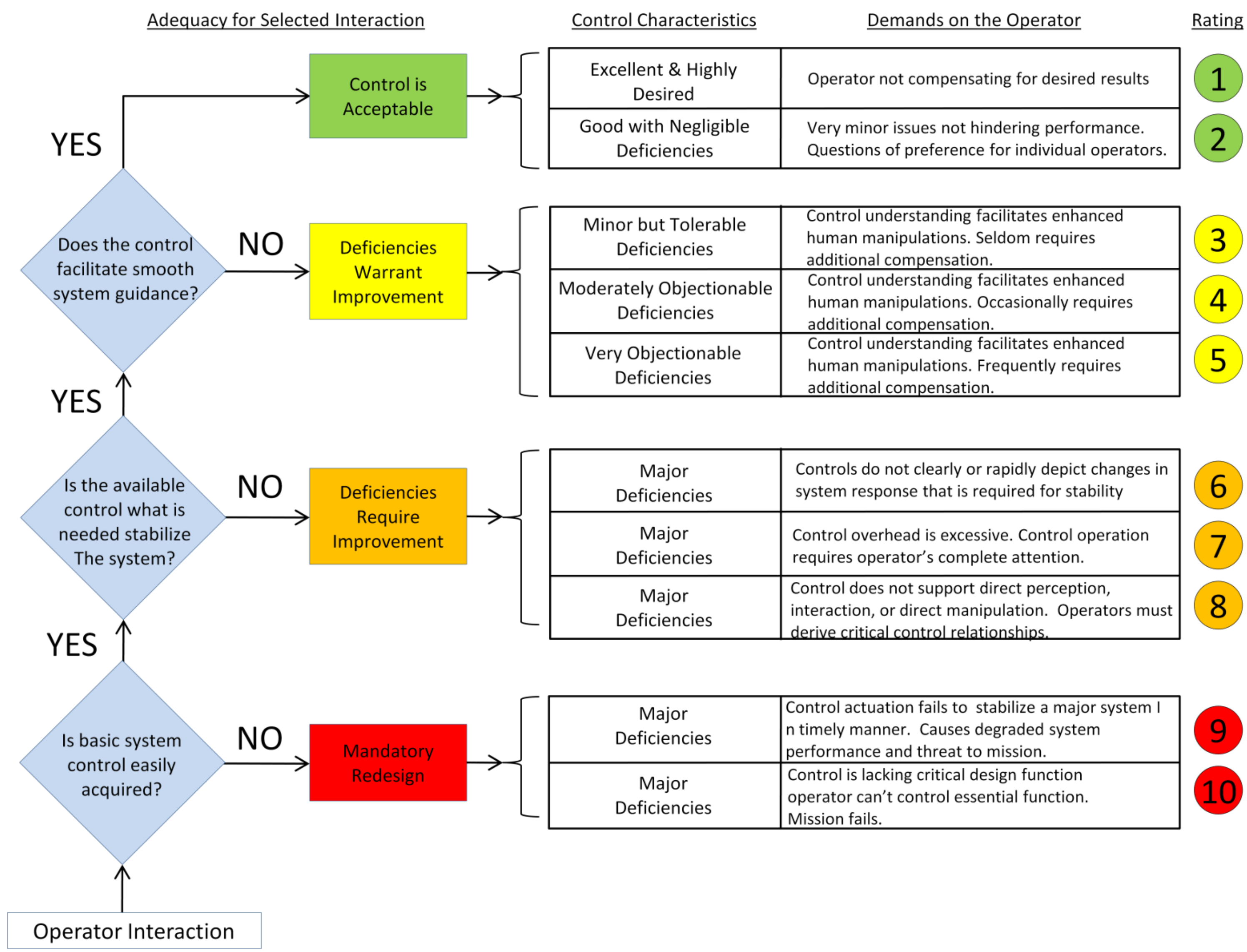
Teleoperation Display Qualities Rating Scale



Appendix F. Modified Cooper-Harper Controls Ratings Form

This appendix appears in its original form, without editorial change.

Teleoperation Control Qualities Rating Scale



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